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Research Development

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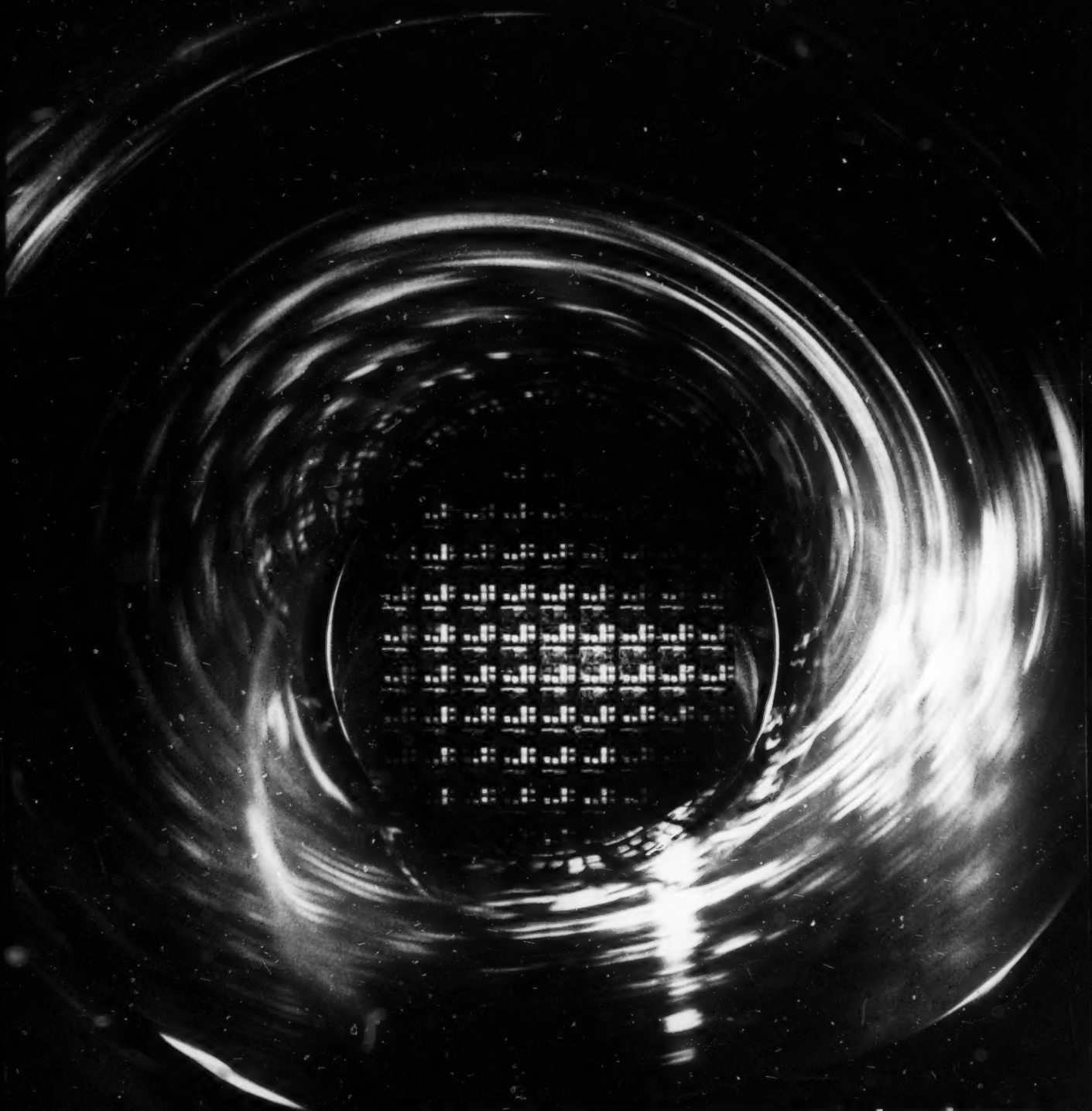

Developments in computer hardware

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Research & Development

The magazine with the R&D 100 Awards

EDITORIAL

9 **Action and reaction**

DEPARTMENTS

15 **Innovative Notebook**
23 **Product Development**
27 **R&D Business**
31 **Research Trendletter**
35 **R/D News in Brief**
99 **Vacuum Technology**
108 **Equipment Literature File**
109 **Industry Events**
111 **New Products**
122 **R&D Product Center**
127 **Literature**
134 **Opinion Poll Results**
135 **Opinion Poll Questionnaire**
137 **Letters**
140 **Advertisers Index**
143 **Reader Service Card**

ABOUT THE COVER

Does BC stand for "before chips"? Chips like those on this silicon wafer may be the basis for computer hardware in your car, instruments, or memory systems. Photo by General Electric R&D Center.

NEWS

39 **R&D funding:** Modest gains for science in FY89; microchip design tools; Link programs approved; UK tax proposal

40 **Technology export:** DOC-Pentagon feud delays export licenses

41 **Space:** U.S. gets new space policy

42 **Astronomy:** Foreign competitors challenge U.S.; 1 AU is 93 million mi

45 **Science policy:** Science's role in White House discussed; U.S. needs more-targeted research; Federal labs' tech transfer to small businesses is lax

49 **Materials:** Silicon moves beyond electronics uses; improved filter

50 **Solar:** Researchers advance amorphous silicon to 15% efficiency threshold

52 **Energy & power:** New technologies will impact utility industry; CFC-113 substitute; CAES to ease load leveling

63 **Computers:** Parallelism takes hold in computer architecture; X Windows standard; AI applied to language translation; scanner reveals inner rock

70 **Aviation:** Computer simulation provides insight into vortex breakdown

ARTICLES

74 **In this high technology success story, everybody benefits:** Robert R. Jones, editor, *R&D*; technology transfer.

80 **It's the word length that determines the computer speed:** J.J. O'Donnell, Multiflow Computer Inc.

88 **Your lab can run itself if you set it up right:** Andrew Corkan, Carnegie-Mellon Univ.; management by GPIB.

92 **Use of electrical and electronic instruments:** C.J. Mosbacher, consultant, *R&D*; Trendsurvey.

99 **Get better wafer uniformity with less waste:** Brad Mattson and Beth Cole, Novellus Systems Inc.; improved CVD.

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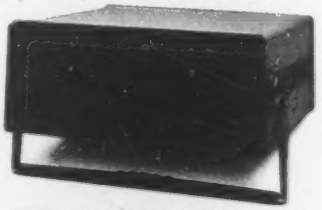

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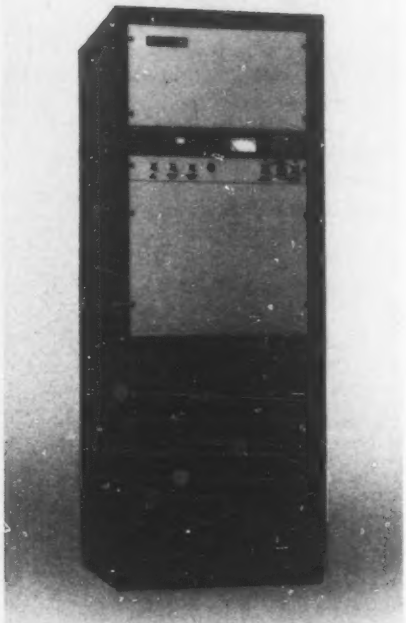

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USE OF ELECTRICAL AND ELECTRONIC INSTRUMENTS

While printer-plotters rank first in both current use and plans to acquire on a total-sample basis, other instruments top them when category-based measures are used.

C.J. Mosbacher
Consultant, *R&D* magazine

OF THE 868 *Research & Development* readers who responded to our most recent Trendsurvey questionnaire, 91.4% currently use at least one type of electrical or electronic instrument or device. In addition, 44.6% plan to acquire one or more within a year. The survey includes 30 categories of electrical/electronic equipment plus a category for "other."

Without the "other" category, which was not included in calculating the numerical data presented in this article, average present use is 26.9% and average plan to acquire is 4.8%. Data for each category of instrument (and equipment) are presented on a total-sample basis in the first bar graph of this article. Detailed data are given in a table that includes a demographic breakdown by the disciplines of the respondents.

The top ten equipment types in current use are printer-plotters, digital voltmeters, digital multimeters, low-voltage dc power supplies, microprocessors, electronic digital thermometers, general-purpose oscilloscopes, time and frequency counters, high-voltage dc power supplies, and frequency generators.

For plans to acquire within one year, the top ten are printer-plotters, microprocessors, data loggers, electronic digital thermometers, digital storage oscilloscopes, digital multimeters, low-voltage dc power supplies, IEEE-488 buses, line conditioners and universal power supplies, and high-voltage dc power supplies. Of the ten categories, six also are included in the top ten for present use.

As previously noted, printer-plotters rank first in both total-sample present use and plan to acquire. Examination of the detailed demographic table shows that printer-plotters rank first in total-sample rankings except in the life-science-or-medicine plan to acquire category. There they rank third, following data loggers and electronic digital thermometers.

Growth rate: another view of the results

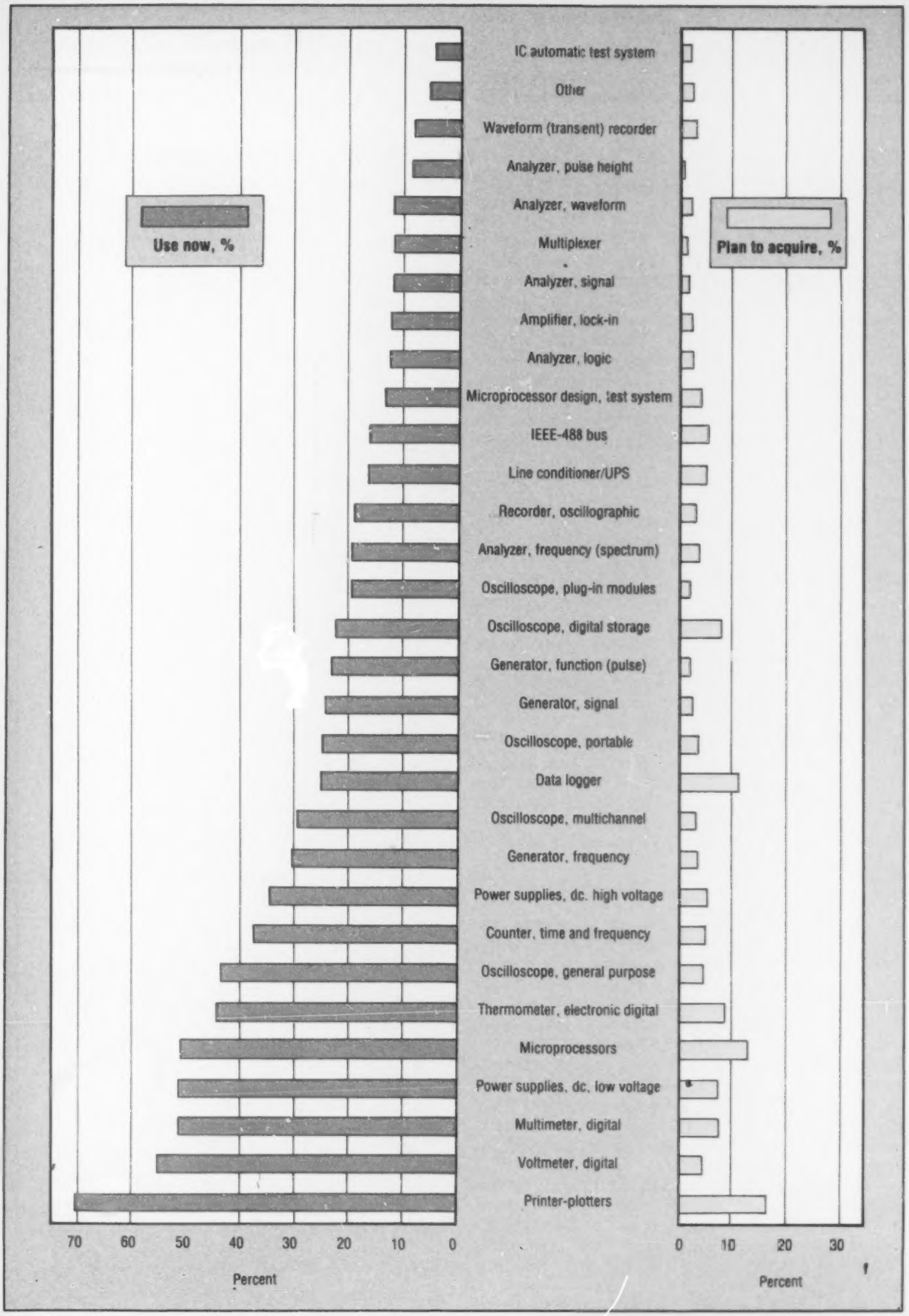
While use now and plan to acquire percentages based on the total sample present the data fairly, they mask an important interpretation of the Trendsurvey data—the growth rate for individual categories.

For example, printer-plotters are used now by 70.3% of respondents and 16.4% plan to acquire them, expressed as percentages of the total of 868 respondents. But by using the 610 respondents who now use printer-plotters as a base by which we divide the 142 respondents who plan to acquire them, we obtain a growth rate of 23.3%. These growth-rate results are presented in the second bar graph and are included in the summary table.

Ranking by total growth rate is shown in the graph. Also shown are rankings from the most recent Trendsurvey of electrical and electronic instruments (*R&D* November 1984, p 114). Possible comparisons of the results of that earlier study will be discussed later in this article.

The top ten rankings in growth rate include only two of those in the total-sample use-now top ten and six of those in the total-sample plan-to-acquire top ten. The average growth rate is 20.0%, which is comprised of 9.4% from present users who plan to acquire and 10.7% from new users (those who did not indicate that they now use that particular instrument but who indicated they plan to acquire it).

The top ten categories of growth rate for present users are: microprocessors, waveform (transient) recorders, data loggers, printer-plotters, microprocessor design and test systems, IEEE-488 buses, digital storage oscilloscopes, line conditioners and universal pow-


Use now, %
Plan to acquire, %
IC automatic test system
Other
Waveform (transient) recorder
Analyzer, pulse height
Analyzer, waveform
Multiplexer
Analyzer, signal
Amplifier, lock-in
Analyzer, logic
Microprocessor design, test system
IEEE-488 bus
Line conditioner/UPS
Recorder, oscillographic
Analyzer, frequency (spectrum)
Oscilloscope, plug-in modules
Oscilloscope, digital storage
Generator, function (pulse)
Generator, signal
Oscilloscope, portable
Data logger
Oscilloscope, multichannel
Generator, frequency
Power supplies, dc, high voltage
Counter, time and frequency
Oscilloscope, general purpose
Thermometer, electronic digital
Microprocessors
Power supplies, dc, low voltage
Multimeter, digital
Voltmeter, digital
Printer-plotters
70 60 50 40 30 20 10 0
Percent
0 10 20 30
Percent

er supplies, electronic digital thermometers and, finally, digital multimeters.

For new users, they are: IC automatic test systems, data loggers, digital storage oscilloscopes, waveform (transient) recorders, line conditioners and universal power supplies, IEEE-488 buses, waveform analyzers, microprocessor design and test systems, frequency (spectrum) analyzers, and logic analyzers.

Demographics: more detail but less reliable

In addition to questions about present use and plans to acquire for each of the 30 instrument categories, respondents were asked to give their job function, employer, and discipline by checking applicable boxes on the reply card. This allowed data for each instrument category to be broken out by demographic group.

Detailed data by primary discipline are given in the summary table. Space precludes detailed discussion of this information. However, averages are given in the following paragraphs.

By discipline, and without the "other" instrument category (as noted earlier this category was not included in any of our calculations), present use averages 33.9% and plan to acquire averages 6.3% for engineering, 22.9% and 3.7% for physical science, and 14.3% and 2.9% for life science or medicine.

By employer, industry averages 25.8% present use and 4.4% plan to acquire, universities 32.4% and 5.6%, nonprofit organizations 26.7% and 4.1%, medical research centers 12.4% and 2.9%, government 28.1% and 4.3%, and other 26.2% and 9.8%.

By job function, corporate officers reported present use as 26.3% and plan to acquire as 9.5%, R&D executives 28.8% and 8.0%, project managers 30.1% and 5.3%, professional staff members 26.3% and 3.7%, and others 24.9% and 3.0%.

While these demographically based data do provide information, they should be used with caution. Statistical reliability suffers when smaller data bases are used, and the number of respondents in some categories such as medical research centers is small. However, the demographic data do allow better comparison with earlier studies.

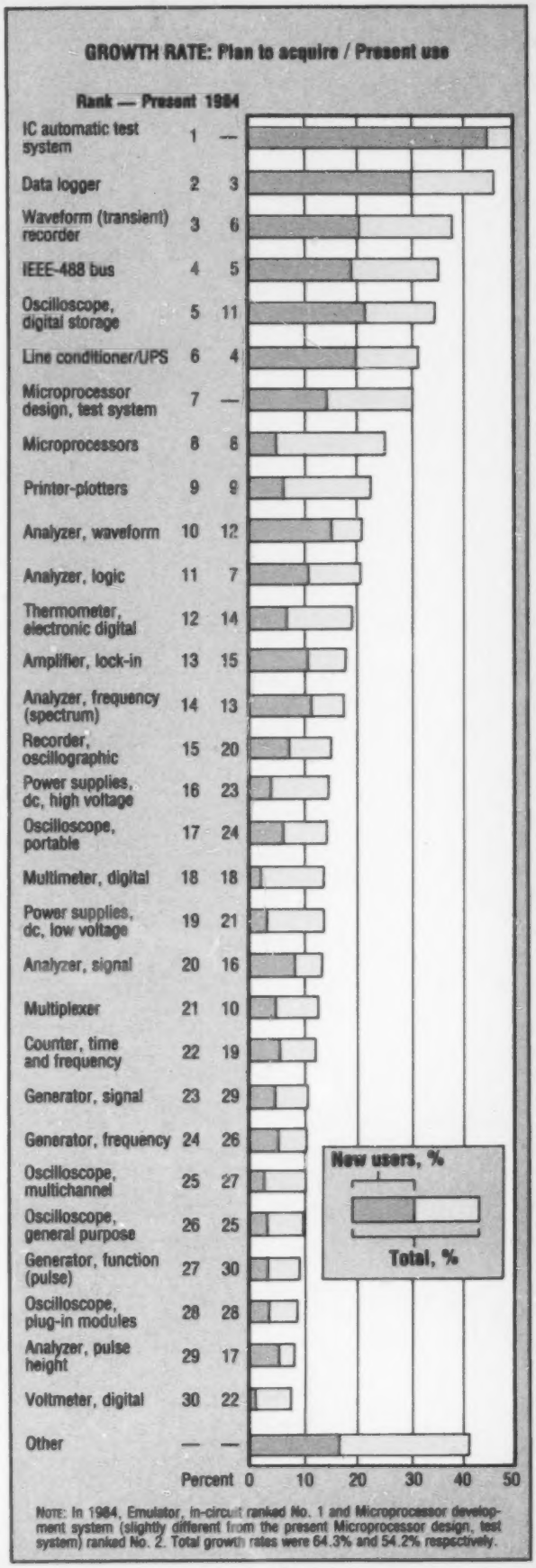
Historical and other comparisons

Several factors make it difficult to compare the present results with those of the 1984 Trendsurvey. First are changes in the demographics of the respondents. Second is the fact that only 28 of the categories are the same in both studies.

First, the demographics. Primary disciplines were much the same, with engineers making up 47.4% of the respondents in 1984 and 47.7% now, physical scientists 35.5% versus 34.2%, and life science or medicine 14.4% versus 13.4% now. The difference is that, in 1984, 2.7% of the respondents gave no answer in this category and 4.7% failed to give their discipline this time.

By employer, 53.6% were in industry in 1984 versus 55.9% now, universities 21.3% versus 18.4% now, nonprofit organizations 6.1% versus 3.0% now, medical research centers 3.3% versus 2.1% now, other 14.0% versus 3.8% now, and no answer 1.7% versus 3.2% now.

Government was not included in the 1984 categor-


GROWTH RATE: Plan to acquire / Present use
Rank — Present 1984
IC automatic test system 1 —
Data logger 2 3
Waveform (transient) recorder 3 6
IEEE-488 bus 4 5
Oscilloscope, digital storage 5 11
Line conditioner/UPS 6 4
Microprocessor design, test system 7 —
Microprocessors 8 8
Printer-plotters 9 9
Analyzer, waveform 10 12
Analyzer, logic 11 7
Thermometer, electronic digital 12 14
Amplifier, lock-in 13 15
Analyzer, frequency (spectrum) 14 13
Recorder, oscillographic 15 20
Power supplies, dc, high voltage 16 23
Oscilloscope, portable 17 24
Multimeter, digital 18 18
Power supplies, dc, low voltage 19 21
Analyzer, signal 20 16
Multiplexer 21 10
Counter, time and frequency 22 19
Generator, signal 23 29
Generator, frequency 24 26
Oscilloscope, multichannel 25 27
Oscilloscope, general purpose 26 25
Generator, function (pulse) 27 30
Oscilloscope, plug-in modules 28 28
Analyzer, pulse height 29 17
Voltmeter, digital 30 22
Other — —
New users, %
Total, %
Percent 0 10 20 30 40 50

NOTE: In 1984, Emulator, in-circuit ranked No. 1 and Microprocessor development system (slightly different from the present Microprocessor design, test system) ranked No. 2. Total growth rates were 64.3% and 54.2% respectively.

PRESENT AND PLANNED USE: Data from 868 respondents	Use now								Plan to acquire within 1 year								Growth rate*			
	Total, 868		Engineering, 414		Physical science, 297		Life science or medicine 116		Total, 868		Engineering, 414		Physical science, 297		Life science or medicine 116		Total	Present users who plan to acquire		New users
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%	No.	%	%
Amplifier, lock-in	107	12.3	45	10.9	50	16.8	6	5.2	20	2.3	7	1.7	11	3.7	1	0.9	18.7	8	7.5	11.2
Analyzer, frequency (spectrum)	172	19.8	117	28.3	42	14.1	5	4.3	31	3.6	21	5.1	6	2.0	1	0.9	18.0	10	5.8	12.2
Analyzer, logic	107	12.3	78	18.8	16	5.4	7	6.0	22	2.5	12	2.9	7	2.4	1	0.9	20.6	10	9.3	11.3
Analyzer, pulse height	73	8.4	36	8.7	29	9.8	4	3.4	6	0.7	4	1.0	2	0.7	0	0.0	8.2	2	2.7	5.5
Analyzer, waveform	100	11.5	68	16.4	23	7.7	2	1.7	21	2.4	12	2.9	5	1.7	3	2.6	21.0	5	5.0	16.0
Analyzer, signal	104	12.0	64	15.5	28	9.4	6	5.2	14	1.6	9	2.2	5	1.7	0	0.0	13.5	5	4.8	8.7
Counter, time and frequency	329	37.9	206	49.8	91	30.6	21	18.1	41	4.7	27	6.5	10	3.4	2	1.7	12.5	22	6.7	5.8
Data logger	218	25.1	130	31.4	58	19.5	19	16.4	103	11.9	62	15.0	23	7.7	13	11.2	47.2	36	16.5	30.7
Generator, frequency	262	30.2	175	42.3	67	22.6	11	9.5	27	3.1	18	4.3	5	1.7	2	1.7	10.3	11	4.2	6.1
Generator, function (pulse)	203	23.4	129	31.2	54	18.2	14	12.1	19	2.2	11	2.7	5	1.7	1	0.9	9.4	13	6.4	3.0
Generator, signal	210	24.2	142	34.3	48	16.2	12	10.3	22	2.5	13	3.1	5	1.7	2	1.7	10.5	12	5.7	4.8
IC automatic test system	40	4.6	27	6.5	10	3.4	1	0.9	20	2.3	15	3.6	3	1.0	2	1.7	50.0	2	5.0	45.0
IEEE-488 bus	142	16.4	84	20.3	51	17.2	5	4.3	50	5.8	30	7.2	17	5.7	3	2.6	35.2	22	15.5	19.7
Line conditioner/UPS	147	16.9	74	17.9	52	17.5	17	14.7	47	5.4	26	6.3	18	6.1	2	1.7	32.0	17	11.6	20.4
Microprocessors	444	51.2	237	57.2	144	48.5	48	41.4	113	13.0	68	16.4	31	10.4	9	7.8	25.5	89	20.0	5.5
Microprocessor design, test system	115	13.2	92	22.2	17	5.7	3	2.6	35	4.0	29	7.0	4	1.3	2	1.7	30.4	18	15.7	14.7
Multimeter, digital	449	51.7	264	63.8	142	47.8	30	25.9	62	7.1	38	9.2	15	5.1	7	6.0	13.8	50	11.1	2.7
Multiplexer	100	11.5	66	15.7	20	6.7	11	9.5	13	1.5	9	2.2	4	1.3	0	0.0	13.0	8	8.0	5.0
Oscilloscope, digital storage	195	22.5	130	31.4	49	16.5	9	7.8	68	7.8	43	10.4	20	6.7	4	3.4	34.9	24	12.3	22.6
Oscilloscope, general purpose	381	43.9	240	58.0	101	34.0	26	22.4	36	4.4	21	5.1	12	4.0	4	3.4	10.0	27	7.1	2.9
Oscilloscope, multi-channel	258	29.7	175	42.3	61	20.5	12	10.3	26	3.0	19	4.6	3	1.0	2	1.7	10.1	19	7.4	2.7
Oscilloscope, plug-in modules	172	19.8	118	28.5	39	13.1	8	6.9	16	1.8	11	2.7	3	1.0	2	1.7	9.3	10	5.8	3.5
Oscilloscope, portable	215	24.8	143	34.5	53	17.8	12	10.3	30	3.5	23	5.6	6	2.0	1	0.9	14.0	15	7.0	7.0
Power supplies, dc, high voltage	301	34.7	153	37.0	114	38.4	22	19.0	45	5.2	29	7.0	11	3.7	3	2.6	15.0	33	11.0	4.0
Power supplies, dc, low voltage	447	51.5	258	62.3	134	45.1	40	34.5	61	7.0	43	10.4	11	3.7	5	4.3	13.6	47	10.5	3.1
Printer-plotters	610	70.3	301	72.7	216	72.7	71	61.2	142	16.4	75	18.1	50	16.8	11	9.5	23.3	98	16.1	7.2
Recorder, oscillographic	165	19.0	105	25.4	37	12.5	16	13.8	25	3.0	23	5.6	0	0.0	3	2.6	15.8	13	7.9	7.9
Thermometer, electronic digital	384	44.2	212	51.2	128	43.1	30	25.9	74	8.5	41	9.9	19	6.4	12	10.3	19.3	44	11.5	7.8
Voltmeter, digital	479	55.2	295	71.3	141	47.5	28	24.1	36	4.1	23	5.6	11	3.7	2	1.7	7.5	27	5.6	1.9
Waveform (transient) recorder	71	8.2	43	10.4	22	7.4	3	2.6	27	3.1	17	4.1	9	3.0	0	0.0	38.0	12	16.9	21.1
Other	51	5.9	19	4.6	16	5.4	15	12.9	21	2.4	8	1.9	7	2.4	5	4.3	41.2	12	23.5	17.6

* Growth rate is calculated by dividing plan to acquire by present use for that particular instrument category.

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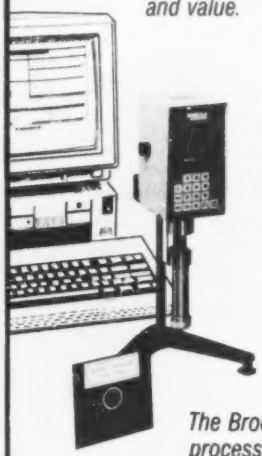

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OPINION POLL RESULTS

Researchers want to do extra, but . . .

IN THE JUNE 1987 issue of *Research & Development* we asked about reader interest in company policies that make it possible for scientists to pursue personal research projects on company time. Of the 700 respondents to the questions, 94% said that they would be interested in doing research other than what is assigned to them, yet only 32% of the respondents work for companies that have such policies.

Of those who work for companies that have personal research policies, 58% have had personal projects result in new products or have improved company processes. It also was encouraging to see that when a personal project results in a worthwhile product, 88% of the scientists are allowed to participate in the product's development. Results of the survey follow.

1. *Are you interested in doing research other than what is assigned to you?*
   a. Yes . . . 94% b. No . . . 6%
2. *Does your company have a policy that encourages personal research projects?*
   a. Yes . . . 32% b. No . . . 68%
3. *Would you like to see your company adopt a policy that promotes personal research projects?*
   a. Yes . . . 83% c. Indifferent . . . 11%
   b. No . . . 2 No Response . . . 3
4. *Would the presence or absence of such a policy be a factor if you were looking for a job?*
   a. Yes . . . 71% b. No . . . 28% NR . . . 1%

The remaining questions pertained only to those whose companies have personal research policies.

5. *How much time is provided by your company to pursue personal research ideas?*
   a. 4 hours or less a week 21%
   b. more than 4 hours a week 9
   c. as much time as I want, provided my regular work gets done 58
   d. company facilities are available, but may only be used on personal time 12
6. *What incentive is there to do personal research?*
   a. bonus if a development becomes profitable or improves a company product 16%
   b. additional vacation time, free trips, or some other perquisite 1
   c. there is no incentive other than personal satisfaction, company loyalty, and a desire to advance my position 83
7. *Have any of your personal research projects ever paid off by becoming a product or by improving a process?*
   a. Yes . . . 58% b. No . . . 40% NR . . . 2%
8. *Do you have to get approval for a personal project idea from a superior?*
   a. Yes . . . 46% b. No . . . 54%

→

OPINION POLL

Will superconductivity ever be practical?

WE ALL HAVE BEEN bombarded by reports in recent months of developments of superconducting materials with ever-rising transition (T_c) temperatures. Most recently, noted superconductor researcher Paul Chu of Univ. of Houston reported development of a bismuth-based material with a T_c of 114 K.

Newspapers, magazines, and television programs have given extensive coverage to this very exciting research field. In addition, virtually every materials-oriented scientific symposium within the past year has included sessions on superconductor research. Though there is little doubt that someday this research work will bear very important and valuable fruit, we would like to know what the readers of *R&D* think about superconductivity, its potential, and when we will begin to harvest this fruit.

Please answer the following questions on the Reader Service card in the back of this issue. Results of this survey will be reported in a future issue.

1. How long do you think it will be before we begin to see practical, affordable applications for superconductive materials?
   a. 5 years
   b. 10 years
   c. 15 years
   d. 20 or more years
2. What do you think will be the first practical application of these materials?
   a. electric utility plants
   b. motor vehicles
   c. small electric motors
   d. computers
   e. some other application
3. When do you think we will see development of a room-temperature superconducting material?
   a. in 5 years
   b. in 10 years
   c. in 20 years
   d. not in the foreseeable future
4. Is development of a room-temperature superconducting material going to be essential before we will see everyday use of superconductive electricity carriers?
   a. Yes
   b. No
   c. Doubtful
5. Is this a research field that should be heavily funded by tax dollars?
   a. Yes
   b. No
6. Has the popular press generally done a credible job of reporting progress in this field?
   a. Yes
   b. No

Opinion Poll Results continued

9. *If it is decided that your reserach project has resulted in something that is worthwhile, are you allowed to participate in its development into a product?*
   a. Yes . . . 51%
   b. Yes, in a limited capacity . . . 37%
   c. No . . . 8%
   NR . . . 4

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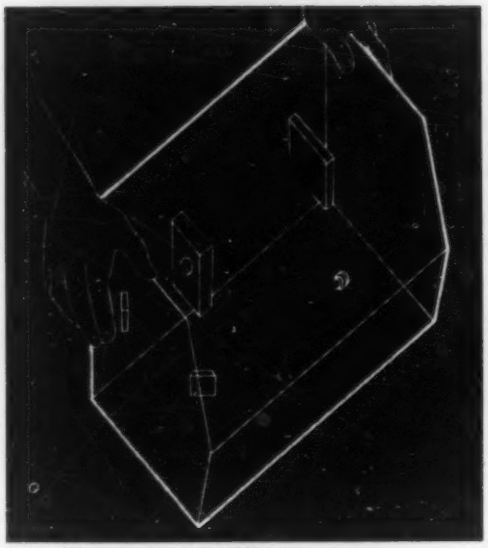

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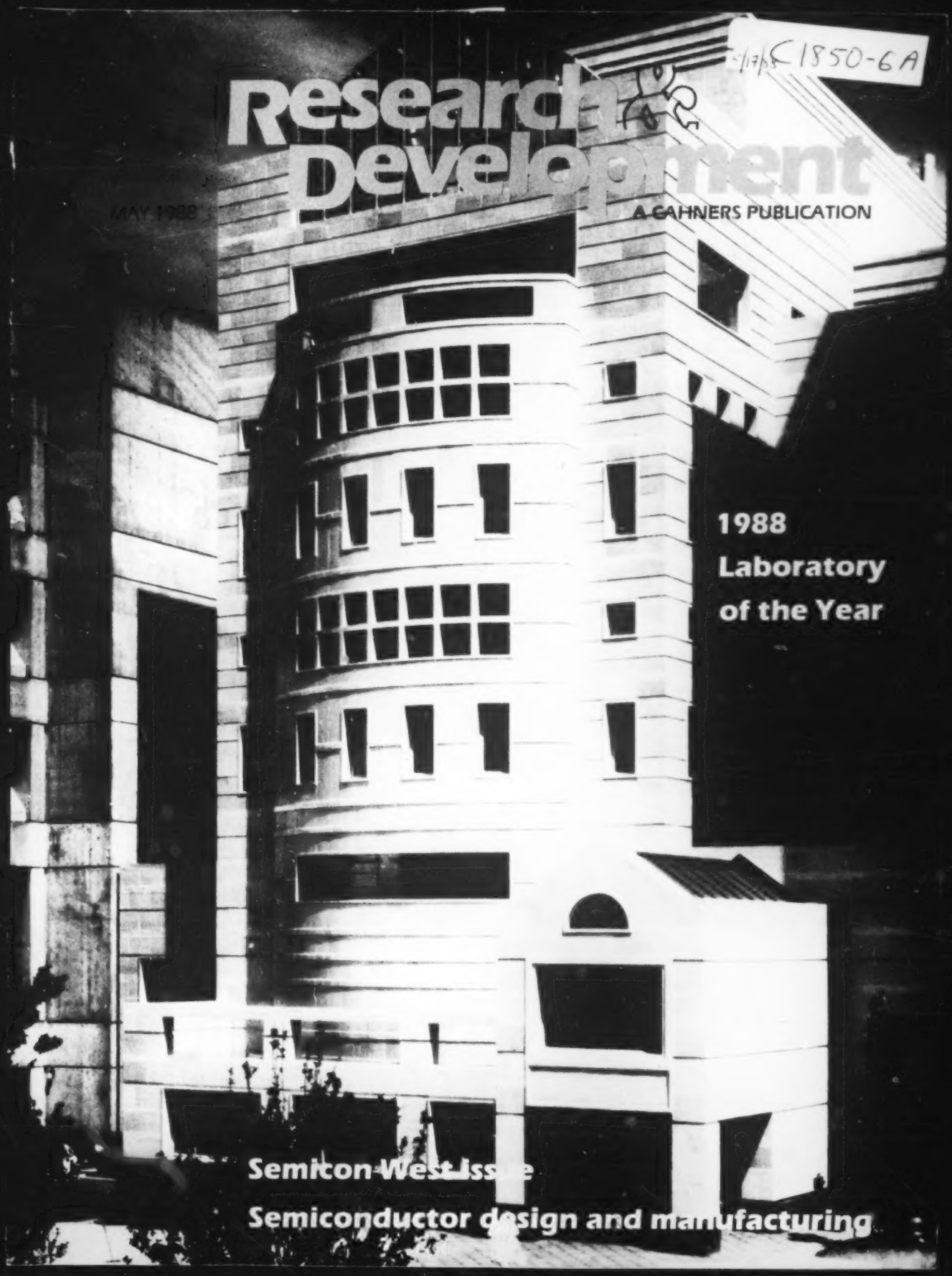

1988 Laboratory of the Year

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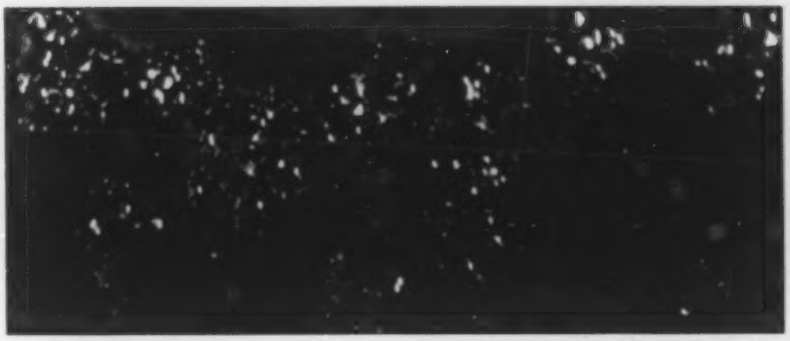
Pseudocolor image for fractal research. **See p 92.**



EDITORIAL

11 Old friend gets new look

DEPARTMENTS

17 Innovative Notebook
23 Product Development
29 R&D Business
33 Research Trendletter
39 R/D News in Brief
97 Vacuum Technology
106 Industry Events
124 Equipment Literature File
131 New Products
146 R&D Product Center
153 Literature
163 Bookshelf
164 Opinion Poll Results
166 Letters
172 Advertisers Index
175 Reader Service Card

ABOUT THE COVER

Research & Development's 1988 Laboratory of the Year is the Vollum Institute for Advanced Biomedical Research, a research division of Oregon Health Sciences Univ., Portland, OR. Planners designed the facility to be a catalyst for university development and to attract to the staff outstanding biomedical researchers and teachers.

High Honors are awarded to the U.S. Dept. of Energy's High Temperature Materials Laboratory and to the Allied-Signal Inc. Charles W. Nichols Jr. Technology Center. Receiving special mention in this year's competition is the DuPont Experimental Station Bldg. 328.

An article beginning on p 68 describes the 1988 Lab of the Year and the other award-winning facilities.

NEWS

45 Technology: Toshiba high-tech sale debate rages in U.S.; UK increases science spending by 8%

45 Computers: New adder circuit could improve computer speed

46 Superconductivity: New mixtures of ceramic oxides yield higher T_c capability; engineers develop high-speed bearing based on ceramic oxides

47 Robotics: Stanford robotic advances are result of freedom to innovate; robotic vision could benefit from eye-coding theory; researchers link together 1,260 transputers; two British studies address use of robots in space; 'UK must focus its efforts in maritime research'

50 Remote sensing: Imaging polarimeter provides better view of Earth geophysics

56 Milestones: New senior editor, Rob Cassidy, will report on business of R&D

58 Solar: Highly concentrated sunlight opens way to many new applications

60 Fuel cells: Subsystem advances brighten the outlook for fuel cells

62 Simulation: 'Strange' devices help engineers study chaotic behavior

64 Aviation: Recent advances could lead to civilian RPV applications; technique produces 3-μm-dia fine powders; thermoplastics used as structural parts on high-performance aircraft

ARTICLES

68 A lab you can live in: H.L. Thomas, editorial consultant, *R&D*; Vollum Institute for Biomedical Research, Portland, OR, is 1988 Lab of the Year. High Honors go to Oak Ridge and Allied-Signal laboratories.

78 R&D industry takes on an entirely new look: Robert R. Jones, editor, *R&D*; trends lead to new profile for the typical worker in research, product development, and quality assurance.

84 Quality control analysis reduces disk drive failures: A.S. Brar and P.B Narayan, Control Data Corp.; analytical studies speed development and testing of new high-density disk drives.

92 There's more in the picture than meets the eye: Fred Wetzler, consultant; image-analysis hardware and software can help you get new details from the images offered by your SEM or TEM.

97 Magnetically confined ECR increases the uniformity of high-density plasmas: Mike Cooke, Electrotech Equipments Ltd.; ECR plasmas offer low-damage anisotropy and ion-energy controls.

112 Find wafer flaws with optical techniques: A. Bivas and R.A. Powell, Varian Assoc. Inc.; optomechanical system provides a nondestructive method for full-wafer maps of properties.

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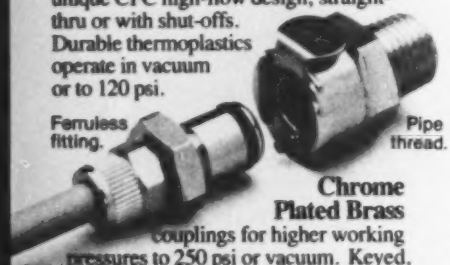

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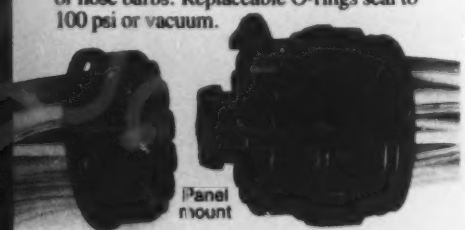

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101

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Robert R. Jones, Editor, *R&D*

R&D industry developing an entirely new look

Changes which appeared as glitches in data several years ago appear to be turning into trends that will develop an entirely new profile for the typical worker in research, development, and quality assurance.

IN THIS second part of our annual profile of the R&D industry (the first part appeared in March), we will look at data which seem to indicate that changes are being made in the profile of the industry—changes other than the usual upward movement of salaries with inflation.

The first article was more general. In this article we will look at some intriguing details. For example, what does it tell us when the proportion of persons responding to this survey who have less than one year's experience has tripled, going from 0.2% two years ago, to 0.4% last year, and to 0.6% this year?

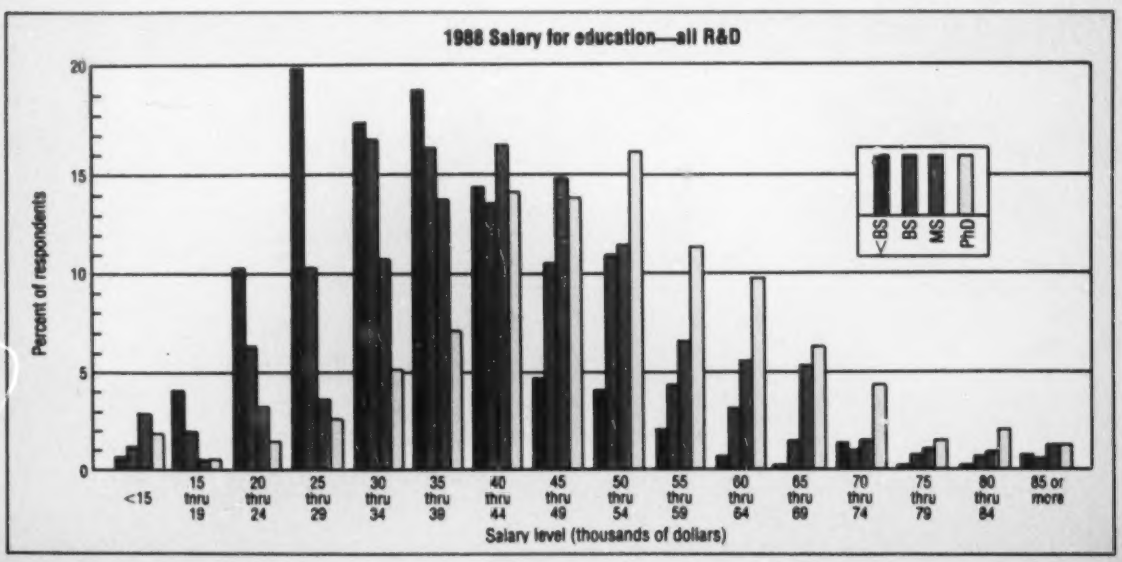
Add to that the fact that those with less than 6 years' experience represented 11.5% of last year's repondents and make up 12.0% this year, an increase of more than 4%. In the same period, the portion of those with more than 35 years' experience declined nearly 21%, having been 6.8% last year and now is 5.4%.

Is it meaningful that the portion who have been with their present employer less than 4 years was 18.1% two years ago and 20.3% last year, and is 21.0% now, an increase of 16%? Or that those earning less than $25,000 per year made up 6.6% of respondents last year and are 7.7% this year, another increase of 16%, and this one in spite of (albeit modest) inflation?

What about the fact that respondents younger than 31 constituted an 11.5% portion in 1986, 12.7% in 1987, and are 13.2% now, an increase of almost 15%? Or that in the past year, the portion older than 55 has declined by nearly 5% from 16.6% to 15.8%?

And finally, how important is it that median salaries for all R&D in our four most-recent surveys of the industry have been 1985, $40,180; 1986, $41,449; 1987, $43,224; and 1988, $43,403? These constitute increases from the preceding years of 6.3%, 3.2%, 4.3%, and 0.42% respectively—a declining rate of increase, no matter how you look at it.

Most of the above changes are small, hardly wor-



thy of mention by themselves, but when there are so many changes happening at the same time, it is hard to say that they hold no significance.

Thus we project an industry with a new profile, only slightly changed from a few years earlier, but still one that is younger, has less experience, has not been with the present employer as long, and is earning a little less in relation to some others than was the case a few years back.

Right now, the people in research, development, and quality assurance make up a strong industry—and there are moves afoot to make the industry even stronger (*e.g.*, formation of the R&D 2000 Committee).

As has been mentioned in other years, this industry pays well for experience, and that was illustrated in a chart in the March issue. Another area that is well rewarded is education. In R&D the premium that is paid for advanced study can be very attractive.

For some reason, perhaps because of early retirement programs, the portion of respondents with PhD degrees in our annual survey has been declining in recent years. After climbing to a high of 33.1% in 1985, the PhD portion dropped to 30.1% in 1986 and 28.0% last year. Now it stands at 29.2%, up more than 4% from a year ago, and in line with figures of the early 1980s.

Biologists have the highest percentage of PhDs at 56.0, up from 52.0 last year and 54.1 the year before. Other PhD percentages are geologists 51.5, physicists 49.0, mathematicians 44.4, ceramists 41.4, metallurgists 40.0, chemists 35.3, aeronautical engineers 21.4, chemical engineers 16.6, electrical engineers 11.8, and mechanical engineers 11.5.

When it comes to advanced degrees, masters plus PhD, geologists lead the way with 84.8% having a PhD or MS. They have displaced physicists from the top position. Other precentages for advanced degrees are physicists 77.6, biologists 72.5, ceramists 69.0, mathematicians 66.7, metallurgists and aeronautical engineers tied at 64.3, chemists 57.2, chemical engineers 47.3, mechanical engineers 42.1, electrical engineers 37.9, and industrial engineers 22.2.

Advanced degrees pay dividends

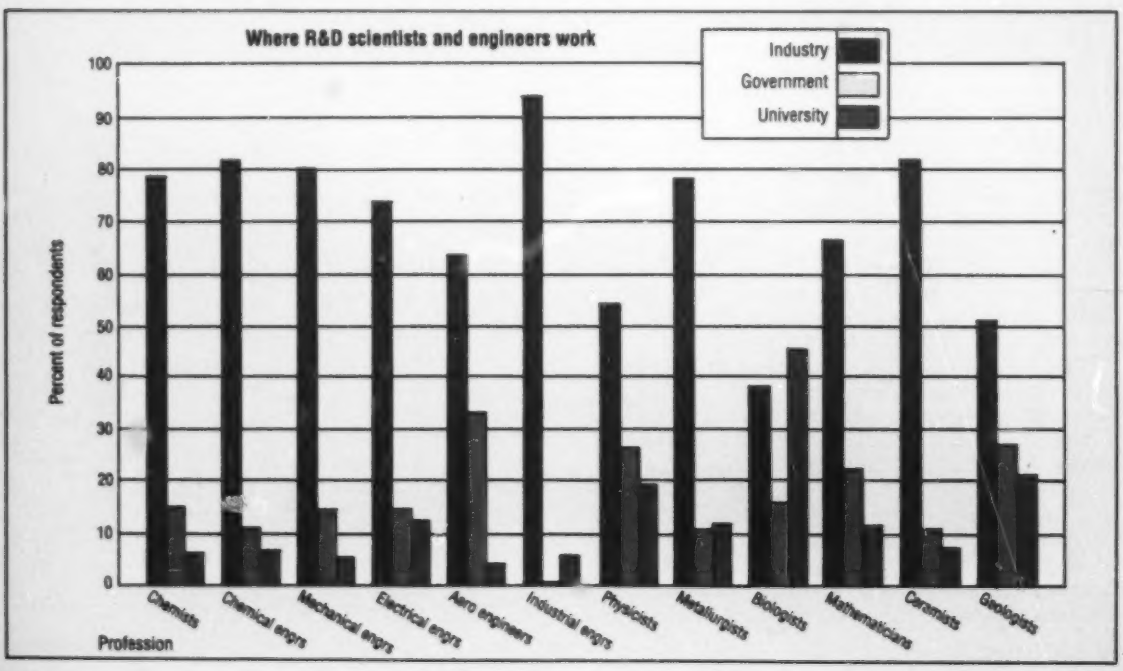
Entirely separate from the personal satisfaction and career advancement that the added education can provide, there is a definite monetary incentive for workers in R&D and QA to go for the higher education.

The research and development scientist or engineer with a doctoral degree can expect a career income advantage of almost $2 million over his colleague who did not go beyond a bachelor degree. At $1,912,000, this figure is up 12.3% from last year's $1,703,000. The figure was $620,000 in 1984.

These, of course, are averages for all of R&D, and the net value for a PhD over a BS depends on an individual's field of endeavor, sex, and whether the employment is in government, university, or industry. Considering the many variables, it is easy to see that many PhDs will reap even greater benefits from their doctorates.

The $2-million-career advantage is what remains after deducting the costs of the added education and allowing for the additional years spent attending classes while the non-PhD was already in the work force. It is assumed that the PhD will work for 35 years after getting the degree, a figure that is supported by the number of respondents who have 35 or more years of experience.

Using similar calculations with different allowances for earning years and expenses, and plugging in the appropriate reported incomes, produces a career advantage figure of $1 million for the PhD over MS de-



grees. This is approximately the same as last year's figure.

When the question arises of going to college and getting a degree, the answer is simple. The career advantage of a baccalaureate degree over no degree is just over three quarters of a million dollars, not bad pay for the first few years out of high school!

It's like earning $465,000 a year

And for the individual with a BS who may be considering a masters program, think big. The difference has increased over last year's and now stands at $930,000, or something like a $465,000 advantage for each year in the masters program. At $930,000, this is up more than 30% from two years ago and up by a factor of 2.7 in four years.

From the beginner's standpoint, looking at college, the potential career advantages, in addition to the BS mentioned above, are MS over less than BS, $1.8 million and—the really big jump—PhD over no degree, $2,662,000 (up 7.3% from last year). This latter advantage works out to being paid $300,000 above expenses for each year spent getting a doctorate.

There are other conclusions that can be drawn from the data about highest academic degree and salaries, as shown in the following table.

R&D salaries compared by academic degrees

Degree	Median salary 1988	Median salary 1987	Percent change	Annual difference* 1988	Annual difference* 1987	Difference change (percent)
Doctorate	$50,955	$50,396	+1.1	$6,350	$6,449	−1.5
Master	44,605	43,947	+1.5	5,537	4,313	+28.4
Bachelor	39,068	39,634	−1.4	4,837	4,986	−2.9
<Bachelor	34,231	34,648	−1.2			

*Difference above next lower degree

In recent years, we have made numerous mentions in this annual report of the discrepancies in salaries for men and women and of the many reasons why some differences are justified. In this year's survey, most of the trends continue unchanged, and one result is that male-female salary and benefit differences are getting smaller.

Premiums continue to be paid for years of experience and longevity with the same employer. The culture of the Anglo-Saxon countries makes it proportionately much more difficult for a woman than a man to acquire long years of technical career experience and to stay for 20 or 30 years with a single employer.

The two charts which appeared on page 57 in the first part of this article (March issue) show—in the first one—how the women respondents to this survey fall far behind the men in years of experience, and—in the second—how highly correlated are experience and salary. Those individuals, either male or female, who have large numbers in years of experience almost always have high numbers in the salary columns.

Exceptions or variations from the above generalization are caused by both sex and workplace (*i.e.*, whether you work in industry, government, or university).

Workplace differences changed substantially a few years ago when industry became the best payer, following several decades when it was a given that people who worked for the government received higher pay than they would if doing the same work for other employers. Industry now is the clear pay leader and—this year—government is only slightly ahead of university.

Median salaries all R&D by workplace

	1988	1987	1980
Government	$41,786	$42,200	$29,733
Industry	44,175	43,887	28,354
University	40,250	38,621	25,685

Sex and workplace trends are borne out in the following table of median salaries. As mentioned above, government rate of pay is losing ground in comparison to industry and university. Thus it is not surprising that median salaries for men in government show a decline from last year's.

And despite all of the problems that remain in the areas of equal treatment for women, the R&D industry is doing some catching up in salaries. In this year's survey results, the smallest percent of salary increase for women is larger than the largest for men.

Having said that, we must also acknowledge that the highest median salary for women (women in industry), remains below the lowest for men (men in universities) by 17.1%.

Median salary by sex and workplace

	1988	1987	% change
Men in industry	$45,111	$44,636	+ 1.1
Men in government	42,667	43,239	− 1.3
Men in universities	41,635	40,521	+ 2.7
Women in industry	35,543	34,437	+ 3.2
Women in government	33,500	30,000	+11.6
Women in universities	27,083	24,318	+11.4

Median salaries are determined by annual increases in rate of pay, and it is clear that women dominated that area last year (salary changes last year that determine rate of pay this year). As shown in the following table, almost half (49.6%) of this year's women respondents to our survey reported annual salary increases of 6% or more. This compares to only 39.3% of the men who received such increases.

Percent receiving R&D salary increases by sex

Granted in Amount of increase	1986 Male	1986 Female	1987 Male	1987 Female
None	16.8	12.8	14.5	14.1
Less than 2%	4.4	3.1	6.6	4.0
2 through 5%	39.6	34.4	50.1	46.3
6 through 9%	30.3	37.8	21.3	24.9
10 through 13%	6.0	6.9	4.6	6.2
14% or more	3.0	4.9	2.9	4.5

Complete results of the survey appear in an accompanying table. R&D

1988 R&D industry profile:

1. What is your annual salary?
   - a. Less than $15,000 ..... 1.9%
   - b. $15,000 to $19,999 ..... 1.3
   - c. $20,000 to $24,999 ..... 4.5
   - d. $25,000 to $29,999 ..... 7.1
   - e. $30,000 to $34,999 ..... 12.1
   - f. $35,000 to $39,999 ..... 13.2
   - g. $40,000 to $44,999 ..... 14.5
   - h. $45,000 to $49,999 ..... 12.1
   - i. $50,000 to $54,999 ..... 12.1
   - j. $55,000 to $59,999 ..... 6.8
   - k. $60,000 to $64,999 ..... 5.6
   - m. $65,000 to $69,999 ..... 3.9
   - n. $70,000 to $74,999 ..... 2.1
   - o. $75,000 to $79,999 ..... 1.0
   - p. $80,000 to $84,999 ..... 1.0
   - q. $85,000 or more 0.8

2. Your raise during the past year was
   - a. None 14.5%
   - b. Less than 2% 6.3
   - c. 2 through 5% 49.8
   - d. 6 through 9% 21.7
   - e. 10 through 13% 4.7
   - f. 14% or more 3.0

3. How long have you worked for your present employer?
   - a. Less than 1 year 4.0%
   - b. 1 through 3 years 17.1
   - c. 4 through 6 years 16.8
   - d. 7 through 9 years 13.3
   - e. 10 through 12 years 10.2
   - f. 13 through 15 years 6.9
   - g. 16 through 18 years 6.2
   - h. 19 through 21 years 7.1
   - i. 22 through 24 years 6.4
   - j. 25 through 27 years 4.5
   - k. 28 through 30 years 3.2
   - m. 31 through 33 years 2.4
   - n. 34 through 36 years 1.2
   - o. More than 36 years 0.8

4. What is your age?
   - a. Under 26 years 2.5%
   - b. 26 through 30 years 10.7
   - c. 31 through 35 years 14.2
   - d. 36 through 40 years 17.4
   - e. 41 through 45 years 14.0
   - f. 46 through 50 years 13.6
   - g. 51 through 55 years 11.7
   - h. 56 through 60 years 10.5
   - i. 61 through 65 years 4.2
   - j. Over 65 years 1.1

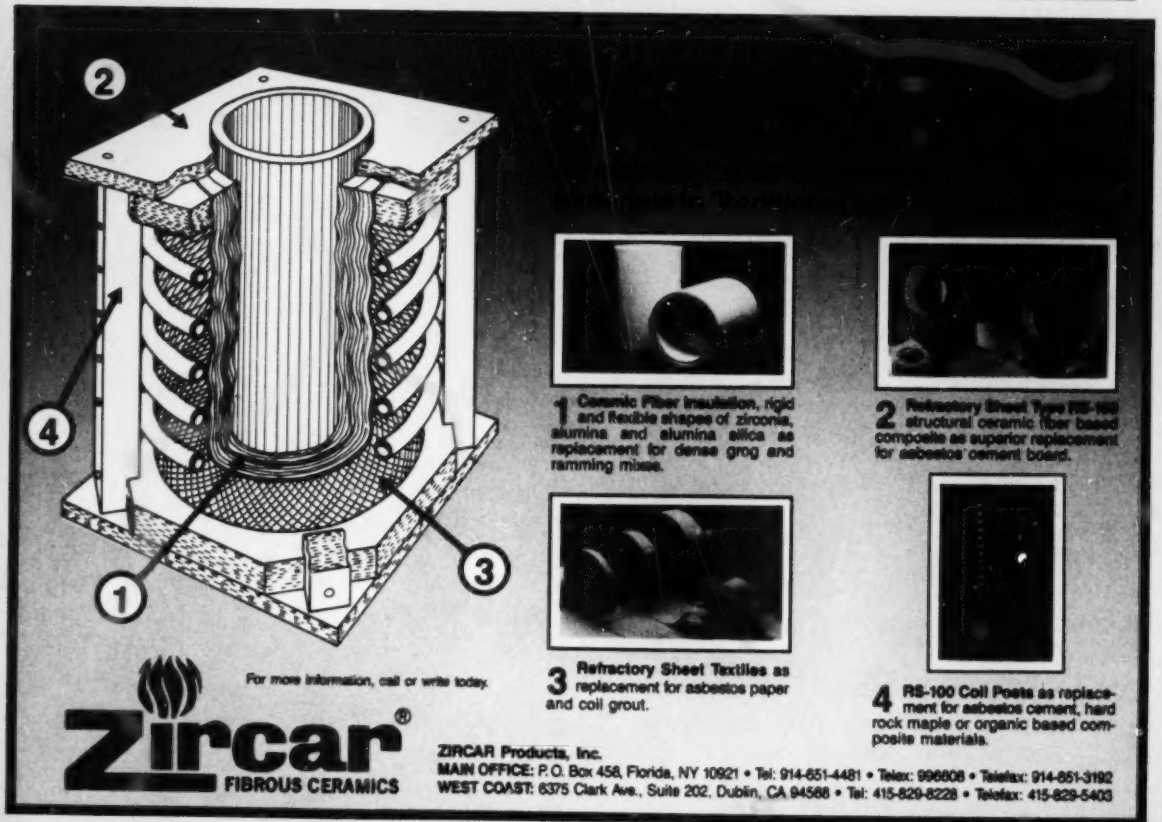
5. How many years of experience do you have?
   - a. Less than 1 year 0.6%
   - b. 1 through 5 years 11.4
   - c. 6 through 10 years 17.8
   - d. 11 through 15 years 16.7
   - e. 16 through 20 years 13.1
   - f. 21 through 25 years 13.6
   - g. 26 through 30 years 12.8
   - h. 31 through 35 years 8.4
   - i. 36 through 40 years 4.0
   - j. More than 40 years 1.4

6. What is the highest degree you hold?
   - a. Less than bachelor 7.8%
   - b. Bachelor 38.3
   - c. Master 24.7
   - d. Doctorate 29.2

7. What is your profession?
   - a. Chemist 36.9%
   - b. Chemical engineer 9.0
   - c. Mechanical engineer ... 11.1
   - d. Electrical engineer 8.5
   - e. Aeronautical engineer . 1.5
   - f. Industrial engineer 1.0
   - g. Physicist 7.6
   - h. Metallurgist 3.7
   - i. Biologist 4.9
   - j. Mathematician 0.5
   - k. Ceramist 1.5
   - m. Geologist 1.7
   - n. Other 12.0

8. Do you work in
   - a. Industry 73.3%
   - b. Government 15.7
   - c. University 11.0

9. Are you
   - a. Male 90.4%
   - b. Female 9.6



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CIRCLE 155 ON INQUIRY CARD

THERE'S MORE IN THE PICTURE THAN MEETS THE EYE

Sophisticated improvements in image-analysis equipment and software get new details from your SEM or TEM.

Fred Wetzler, Consultant

PHOTOGRAPHIC IMAGES, especially in optical or electron-beam photomicrographs, contain a lot more information than the human eye can discern. Fortunately, digital image-analysis equipment has revolutionized the extraction of information from images of both solid and particulate materials.

Today's application-specific image-analysis software packages make it easy for users to perform many types of complex analyses. Advances in digital image-analysis technology include coupling scanning and transmission electron microscopes (SEMs and TEMs) with backscattered-electron detectors and energy-dispersive x-ray spectrometers.

Since they no longer are confined to optical microscopy image analysis, where spatial resolution is limited to about 3 μm, digital image microanalyzers now can take advantage of the high magnification capabilities of SEMs, TEMs, and scanning transmission electron microscopes.

Images in data base

For example, you can use your SEM image analyzer for R&D or for industrial-process investigation to collect, analyze, correlate, and store image data. You, then, can extract from your data base information from stored images or from morphological or object-classification files previously stored for reference.

In one such application, you might mount a backscattered-electron detector on an SEM. You then can perform image microanalysis of a specimen by grey-level segmentation. The data obtained are directly related to the average atomic number of each element in the sample surface.

The addition of an energy-dispersive x-ray spectrometer (EDS) stage to an SEM can provide a means for directly correlating chemical classification data with morphological data, such as particle size, shape, aspect ratio, and other statistically derived data.

These capabilities, then, open a large realm of possibilities for investigation. Some of the areas of recent interest are the study and analysis of geological samples, air-pollution components, composite and ceramic materials, manufactured and natural fiber configurations, food contaminants, aerosols, submicrometer features of semiconductor devices and materials, microorganisms, and biomedical cell-pathology investigations.

Many image-analysis systems now use nondestructive testing (NDT) techniques to control complex laboratory procedures or manufacturing processes. Still other systems use NDT procedures off-line to aid in the assurance of product quality.

Highly magnified images

As researchers gained experience with digital imaging techniques, they found that a common set of techniques often could be used for many widely different analytical applications. For this reason, digital image analysis is becoming an important concept for NDT and quality assurance labs in materials science,

A COMPUTER-GENERATED pseudocolor image derived from a Mandelbrot number set shows the versatility of the computer as well as the high resolution obtainable in the displays of the image analyzer. In addition, an analyzer can make critical-dimension measurements from either a live or an acquired scanning electron microscope or optical microscope image. (Photos—Tracor Northern, Madison, WI.)

biomedical, and industrial studies. And combining digital image analysis with sophisticated numerical analysis routines offers versatile microanalytical tools for R&D in these fields.

One area that requires such critical high-resolution, high-magnification image analysis is in-process inspection of semiconductor wafers and submicrometer-scale masks for voids, pits, and contaminants among the features on the surface.

The submicrometer world of ultrahigh-speed integrated circuits (UHSIC) is here. Nevertheless, the image-analysis engines needed to measure and inspect the submicrometer features are yet to come. Semiconductor manufacturers expect, however, that within three years, image-analysis techniques will have been developed to meet the demand.

Already, practical applications for image analysis exist in a number of major technical fields. Here are a few examples.

Metallurgical analysis

Digital image analysis has been useful in metallurgy for investigating and classifying raw-material properties and for in-process NDT and quality assurance applications for both raw materials and finished products.

□ Measurement and analysis of the inclusions in steel yield information that can indicate how readily machinable the steel will be. Image processing permits grey-level discrimination between sulfides and the steel matrix. Globular inclusions of manganese sulfide can be measured by image analysis.

□ Analysis of the phase composition of processed raw materials can determine the relative proportions of different phases and components. This information lets the researcher predict physicochemical behavior in a furnace, for example, and allows assessment of the potential of a given sample for various uses.

□ Determining grain size, shape, and orientation provides an indication of end-use properties and per-

SEM image-analysis equipment installed worldwide

	Microscopes	Image-analysis systems
1987	10,000 to 15,000	1,500 to 2,000
1990	11,740 to 17,610	3,690 to 4,920
Gain/yr	5.5%	35%

mits making up quality assurance charts for specific drawing applications or for expected properties of grain-oriented steel.

□ Emerging metallurgical applications include fractal analysis for characterizing materials by their fractal dimension (Mandelbrot, B.B., *Form, Chance, and Dimension*, Freeman & Co., San Francisco, 1977).

Analysis of ceramics and composites

Ceramics and composites are multiphase materials in which each phase has a specific function and contributes a specific set of properties. For such a material, image analysis can provide a wealth of pertinent information.

For example, in a fiber/matrix composite such as glass-fiber-reinforced polyester resin, image analysis can determine the uniformity of spacing between fibers as well as the orientation of the fibers and the degree of fiber packing.

In addition, the composition of the individual phases is important. Other critical information obtainable by image analysis is the void count—the number and size of voids and the area that voids occupy relative to the total surface area.

For ceramics, a manufacturer needs to know the porosity, the grain size, the distribution and quantity of additives, and the oversize-grain count. Image analysis can provide this information.

In textile fibers, digital image analysis can obtain information on the fiber shape, the location and severity of bends and kinks, fiber surface area, number of fibers/unit area, and the number and size of holes.

Biomedical analysis

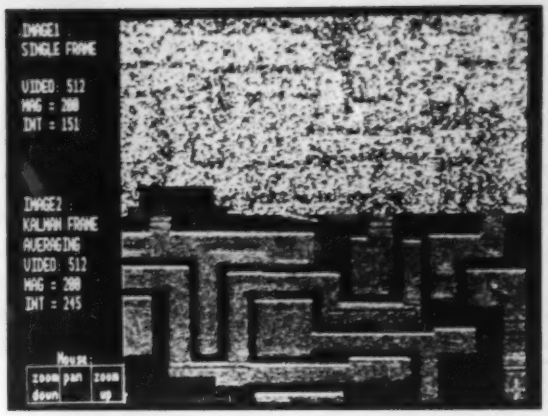
Pathological problems of our aging population are requiring more and more analytical clinical testing. For these tedious manual procedures in, say, multiple-field tissue biopsies, the present practical limit of 100 tests/day in a single lab is inadequate to meet increasing demands. To speed up this type of testing, with equal or better resolution, compared to manual techniques, the field of digital image analysis is about to enter a period of rapid application growth.

Digital image analysis also can address other areas that are putting demands on clinical testing labs. One of the needs is the acceleration of information throughput—getting answers faster than is possible by manual methods.

Other areas include the detection of abnormal cells by rudimentary pattern recognition, the need to communicate clinical data to and from hospitals' host computers, the capability for the clinician to interact with the data system (*i.e.*, to enter information into a data base, to update information in the data base, and to act on data received from both the data base and experimental results), and a facility for storing x-ray picture data in a computer-retrievable data bank.

Major areas in which image analysis already is a strong factor are chromosome kerotyping and the analysis of cells and nuclei to detect the presence of cancer.

In addition, several emerging biomedical applications are relying heavily on image analysis. These include such varied areas as sperm imaging to determine fertility or infertility, immunofluorescence imaging, analysis of bone fragments to determine host signature, bone growth studies, dentistry, surface chemistry to determine lung surfactants, neuroscience, and studies on food contaminants and infestations.



THE UPPER IMAGE shows a single-frame acquisition from an uncoated integrated circuit. The lower image shows the improvement available, using Kalman averaging.

Environmental applications

Digital image analysis can simplify characterization of features and analysis of particles. For this reason, this has become the principal investigative technique in environmental research. Problems addressed include the determination of the particle content of aerosols, ocean samples, atmospheric dust, and filtration products.

Geological imaging analysis, on the other hand, is primarily concentrated on measurement of features, morphology, the occurrence and identification of phases and elements, and the determination of the composition of minerals and other mixtures of materials. For example, typical investigative applications would include the study of air pollutants and atmospheric transport of particulate matter. Likewise, studies of particulate inclusions in biological tissue and of heavy metal occurrences in the environment also are gaining in importance.

Other researchers are using image analysis to obtain data on locked *vs* liberated mineral compositions, the occurrence of useful minerals in ocean mining operations, exploration for petroleum, the amounts and types of particulates in automotive exhaust, and in solving problems in forensic science. In addition, image analysis can give useful information in the detection and identification of precious metals such as gold in mineral matrices.

At present, the lack of adequate baseline standards for geochemical parameters is hindering the growth of image analysis as a tool for environmental research. As a stopgap measure, individual imaging-equipment vendors provide proprietary data bases for chemical definition.

Molecular modeling

Often described as a computer-graphic "Tinker Toy," molecular modeling is an emerging technique that can present on a CRT screen many of the structur-